Radial head fracture: a potentially complex injury
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ABSTRACT

Radial head fractures are common injuries and are accompanied by clinically relevant associated injuries in over one third of the patients. They are commonly classified by the Mason classification, or one of its modifications. Type I fractures are treated conservatively with early mobilization. Type II fractures can be treated conservatively or by open reduction and internal fixation (ORIF), depending on fragment size and dislocation. Bony restriction in forearm rotation is an indication for surgical treatment. Type III fractures are treated surgically, by means of ORIF, prosthetic replacement or excision. Comminuted fractures with > 3 fragments are regarded by some authors as unsuitable for ORIF. However, optimal treatment of type II and III fractures is still subject of debate and there is a strong need of randomized clinical trials and uniform fracture classification and outcome measures.
INTRODUCTION

Although the prognosis of most isolated radial head fractures is good, in 1935 Jones already stated that: “The fracture of the head of the radius is a serious injury, and whilst the prognosis is good for recovery of a useful elbow, rarely it is a normal elbow.” Complications such as loss of elbow motion or persistent elbow pain are frequently encountered. Over the past few years, there is an increasing understanding of the trauma mechanism of radial head fractures, of the clinical importance of their associated injuries and of the role of the radial head in elbow biomechanics. In this review the incidence and etiology of radial head fractures are described, an overview of the classification of radial head fractures is given, the importance of associated injuries is discussed and a treatment rationale for radial head fractures is suggested.

INCIDENCE AND ETIOLOGY

Fracture of the radial head accounts for up to one third of all elbow fractures. The incidence is estimated at 2.5 to 2.9 per 10,000 per year. Radial head fractures are most often the result from a fall on the outstretched hand with the elbow partially flexed and pronated. Amis and Miller correlated elbow fractures to the angle of flexion of the elbow during a fall, the so-called “arc of injury”. In their experimental studies, the radial head only fractures at a flexion angle between 0 and 80 degrees. With flexion of < 35 degrees either the coronoid process or the radial head (or both) may fracture. The radial head plays an important role in maintaining elbow stability. The ulnohumeral articulation in combination with the medial and lateral collateral ligaments are the three primary static stabilizers of the elbow. Secondary constraints include the radial head, the joint capsule and the common flexor and extensor origins. The muscles around the elbow, especially the anconeus, triceps and biceps, function as dynamic stabilizers. If the coronoid process or medial collateral ligament (MCL) are injured, the radial head becomes a critical stabilizer.

FRACTURE CLASSIFICATION

A variety of classification systems for radial head fractures have been developed, of which most are based on the classification introduced by Mason in his classic paper of 1954. (Table I) According to the Mason classification, radial head fractures are divided into three types corresponding to the radiological findings: A type I fracture is a fissure or marginal fracture without displacement, a type II fracture is a marginal sector fracture with displacement and type III fractures are comminuted, involving the entire radial head.
added a fourth type to the Mason classification: radial head fracture with dislocation of the elbow joint.\textsuperscript{10} Intra-observer agreement of the Mason classification is satisfactory and inter-observer agreement moderate.\textsuperscript{11}

Hotchkiss quantified the amount of displacement in his management-based classification: type I indicates a fracture that is ≤ 2 mm displaced, a type II fracture is > 2 mm displaced but amenable to internal fixation, a type III fracture is comminuted and not amenable to internal fixation.\textsuperscript{12} The inter-observer reliability of the Hotchkiss modification is moderate, with a κ-statistic of 0.585.\textsuperscript{13} The Broberg and Morrey modification states that a displacement of ≥ 30% of the articular surface and a dislocation of > 2 mm should be considered as a Mason type II fracture, opposed to the non-displaced type I fracture.\textsuperscript{14} Intra-observer agreement is excellent, and inter-observer agreement is moderate.\textsuperscript{15} van Riet et al. developed the Mason-Mayo classification which includes the associated osseous and ligamentous injuries of the elbow by adding a suffix for injury to the olecranon, coronoid and/or ligaments to the Mason classification.\textsuperscript{16} Intra-observer agreement of the Mason-Mayo classification is fair, and inter-observer agreement ranges from fair to moderate.\textsuperscript{11}

The AO Foundation developed the AO classification for long bone fractures.\textsuperscript{17} Fractures of the proximal radius and ulna are divided into 3 types: type A (extra-articular fracture of radius and/or ulna), type B (intra-articular fracture of one forearm bone, with or without an extra-articular fracture of the other bone) and type C (intra-articular fracture of both radius and ulna). The fractures are then subdivided into groups 1, 2 and 3 for involvement of radius and/or ulna, and the location of the fracture line. These are then further subdivided into subgroups 0.1, 0.2 or 0.3, based on fracture characteristics as comminution. Inter-observer reliability ranges from poor to fair and intra-observer agreement is graded as poor, possibly due to the complexity of the AO classification.\textsuperscript{11, 23} This classification system for radial head fractures is less frequently used in daily clinical practice.

The original Mason classification and its variations are all commonly used in literature. For this current concept article the original Mason classification\textsuperscript{3} is used for practical rea-
sons: when discussing management of radial head fractures, the original articles uniformly have used the Mason classification or one of its modifications. These modifications can all be reduced to original the Mason classification, allowing discussion of the combined results. If the results of a single article are referred, the classification of this original research is used.

ASSOCIATED INJURIES

The importance of concomitant injuries in the treatment of patients with a radial head fracture is increasingly appreciated. In a retrospective study by van Riet et al.\textsuperscript{18} of 333 patients with a radial head fracture, clinically relevant associated injuries of the ipsilateral upper extremity were diagnosed in 39\% of the patients. There is a strong correlation between the likelihood of associated injury and the severity of the radial head fracture: the incidence can increase from 20\% in Mason type I fractures to 80\% in type III fractures.\textsuperscript{18} Loss of cortical contact between fracture fragments in type II fractures is also strongly predictive for a complex injury pattern.\textsuperscript{19} Using magnetic resonance imaging (MRI), associated injuries ranging from ligamentous injuries to capitellar bone bruise can be found in 76 to 96\% of the patients with a radial head fracture.\textsuperscript{20, 21} However, the majority of these injuries probably have no clinical relevance.\textsuperscript{22} Hausmann et al. found partial lesions of the interosseous membrane (IOM) with MRI in 9 of 14 patients with a Mason type I fracture, of which 7 reported pain in the region on the distal IOM.

Ligamentous injuries

As the radial head fractures with the elbow in flexion and pronation with the hand fixed on the ground, the lateral collateral ligament (LCL) ruptures as a result of the forced supination of the forearm when the body rotates internally on the elbow under axial compression as the body approaches the ground. If the rotational and axial forces continue a posterolateral dislocation finally can occur, with or without rupture of the MCL. The MCL can also rupture as a result of a valgus moment.\textsuperscript{23, 24} Ligamentous injuries are found with MRI in 61 to 80\% of the patients with a radial head fracture.\textsuperscript{21} van Riet et al. found a clinically relevant LCL lesion in 11\% of the cases, a MCL lesion in 1.5\% and a combination of both MCL and LCL lesions in 6\%.\textsuperscript{18}

Elbow dislocation, coronoid process fractures and the “terrible triad of the elbow”

Three to 14\% of all radial head fractures is accompanied by a posterolateral dislocation of the elbow. It occurs after a fall on the (nearly) extended arm.\textsuperscript{7, 18} During posterolateral dislocation the ligamentous structures and the capsule are ruptured in a circle from lateral to medial.\textsuperscript{23} The axial compression and supination cause the LCL to rupture, which
results in a posterolateral rotator movement of the forearm. After rupture of the dorsal and ventral elbow capsule the elbow joint dislocates as a result of the axial forces. The coronoid process is pushed under the trochlea of the humerus, causing a shear fracture. Until this phase the dislocated elbow can self-reduce. Finally the MCL ruptures as the coronoid process is pushed further under and behind the trochlea, but this does not occur in all cases. The combination of an elbow dislocation, radial head fracture and coronoid fracture is called “the terrible triad of the elbow” because it can result in severe joint instability and many post-traumatic complications.

Ulnar fractures
A concomitant fracture of the ulna occurs in 1.2-12% of the patients with a radial head fracture. A special variety of the combination of a radial head fracture and an ulnar fracture is the Monteggia lesion (radial head dislocation and fracture of the distal one third of the ulna). It occurs after a fall on the outstretched arm with the forearm in hyperpronation. In complex proximal ulna fractures, Monteggia-like dislocation of the fractured radial head has been described as well.

Capitellar injuries
As the radial head forcefully comes into contact with the capitellum under the axial loading, osteochondral lesions can occur. Capitellar injuries are seen with MRI in 39 to 96% of patients with a radial head fracture. Capitellar fractures occur in 2%. Capitellar fractures occur in 2%.

Other associated injuries
- An acute longitudinal radioulnar dissociation (ALRUD) or Essex-Lopresti-lesion results from a high-energy axial loading, which causes a radial head fracture, rupture of the IOM between radius and ulna and a rupture of the triangular fibrocartilage complex. Although this is a rare injury, Hausmann et al. reported on partial ruptures of the IOM diagnosed with MRI in 9 of 14 patients with a Mason type I fracture, suggesting that injuries of the IOM are more frequent than generally expected.
  - Severe anterior displacement of the radial head may cause injury to the radial nerve. Posterior interosseous nerve injury after radial head fracture has also been reported in literature.
  - Brachial artery injury occurs in 0.3 to 1.7% of the elbow dislocations. Neurologic problems occur in 20% of the elbow dislocations. The ulnar and median nerve are most susceptible.
ASSESSMENT AND IMAGING

Patients with a radial head fracture usually present after a fall with elbow pain. On physical examination the radial head is painful on palpation and an haemarthrosis is seen. Elbow range of motion, especially pro- and supination, is decreased because of pain. Ligamentous injury can be suspected in case of pain on palpation and/or ecchymosis of the medial and/or lateral aspects of the elbow. Aspiration of the haemarthrosis and intra-articular injection of a local anesthetic can be helpful in determining if a restriction in motion is a consequence of pain or a true mechanical block. In case of pain and swelling of the wrist and forearm an ALRUD should be suspected. In case of an elbow dislocation the forearm bones are displaced in a posterolateral direction in relation to the distal humerus in most cases. Stability and neurovascular status should be examined. The diagnosis can be made with lateral and anteroposterior (AP) radiographs of the elbow. A positive fat-pad sign, caused by the haemarthrosis, can indicate presence of a radial head fracture. An additional radial head-capitellum (RHC) view is assumed to reveal the degree of displacement. On the other hand, no significant increase in inter- and intra-observer agreement is seen if this RHC view is performed. If one suspects an ALRUD, additional radiographs of the forearm and wrist should be made, to see if proximal migration of the radius is present. Rupture of the interosseous membrane can be diagnosed with MRI. A computer tomography (CT) scan is indicated in case of coronoid or capitellar fractures, or in Mason-Broberg type II fractures to determine the amount of dislocation or for pre-operative planning.

TREATMENT

Restoration of stability and a pain free range of motion (especially rotation and extension) is the main objective when treating radial head fractures. In Mason type I fractures this will be achieved in most cases, but more complex radial head fractures, with or without associated injuries, demand a careful and individual approach. Complex injuries with forearm instability, such as an ALRUD or coronoid fracture, require restoration of the ulnohumeral joint and the radiocapitellar contact in order to maintain a stable elbow joint. In this review, we focus on the treatment of the radial head fracture as such. Concomitant injuries should be treated within their own merit and are not discussed.

Mason type I

It is generally agreed that type I fractures can be treated with early mobilization. Aspiration of the elbow joint can be performed, as 1cc of intra-articular fluid decreases the range of motion (ROM) with 2 degrees. Intra-articular injection of an anaesthetic does not improve functional results. Good results are achieved in 85 to 95%.
Mason type II

The treatment of type II radial head fractures is still at debate. Dislocation of > 2 mm and a lack of forearm rotation due to bony obstruction of the malformed radial head have been regarded as an indication for surgical treatment. Several techniques and materials for ORIF, e.g. Herbert screws, FFS-screws, biodegradable screws and mini plates, have been described with in general satisfactory results of > 85% (Figs 1 and 2). Biodegradable screws have comparable outcomes compared to standard implant materials for ORIF of radial head fractures. In a study with long-term results of ORIF in 16 patients are good
in 81%, after an average follow-up of 22 years. Arthroscopic reduction and percutaneous fixation of Mason type II (and III) fractures is described by Michels et al. and Rolla et al. This minimally invasive technique is technically demanding, but adequate reduction under visualization and evaluation of associated injuries can be achieved. So far, the arthroscopic technique has not been proven to give superior results in the treatment of radial head fractures, in comparison to ORIF.

Akesson et al. reviewed the long-term results of conservative treatment of Mason-Broberg type II fractures with at least 2 mm of displacement: 82 to 100% had no or minor elbow complaints and a good functional outcome. Therefore, Lindenhovius et al. suggest that stable, isolated Mason-Broberg type II fractures with unrestricted forearm rotation can be treated conservatively, as ORIF does not necessarily lead to better functional results. If the elbow remains symptomatic, a delayed radial head excision or replacement with a radial head prosthesis can be performed. We conclude that randomized clinical trials are needed to determine which type II fractures can be treated conservatively and which require surgical treatment.

**Mason type III**

Treatment of type III fractures is usually surgical: ORIF, prosthetic replacement or excision (Fig. 3). The preferred surgical treatment is still in debate. Comminuted fractures can be treated with ORIF if a stable, reliable reconstruction can be achieved. Successful treatment of type III fractures with ORIF has been reported in 80 to 100%. However, in a study by Ring et al., 10 of 14 patients with a fracture consisting of > 3 fragments treated with...
ORIF needed a delayed excision due to failure of the osteosynthesis, non-union and/or a poor forearm rotation. In these cases, the authors advise prosthetic replacement.\(^{55}\)

Radial head prostheses come in a variety of designs: monoblock or modular prostheses are available. The modular prostheses can be monopolar or bipolar (Fig. 4). The fixation of the implant can be cemented, press fit or “intentional loose fit”.\(^{56-58}\) Intentional loose fit prostheses allow a degree of play, which compensates the anatomic difference of the native and prosthetic radial head during elbow motion. Fixed stems rely on their position and approximation of the native anatomy to achieve congruency with the capitellum and the lesser sigmoid notch. Bipolar prostheses (available in cemented and press fit stem varieties) allow centering of the radiocapitellar joint as a result of an articulation at the head-neck junction and are more forgiving in alignment of the prosthesis in relation to the capitellum.\(^{59}\) The bipolar implants are believed to reduce forces across the capitellum\(^{60}\); however clinical studies to support this theory are not available yet. Cadaveric studies show that bipolar implants provide less mechanic stability, compared to monopolar implants.\(^{60, 61}\) This has not been supported by clinical studies yet.

Short to medium-term results of radial head prostheses are promising.\(^{62-64}\) Complications as overstuffing, nerve injury and dislocation of the implant have been described in up to 20%.\(^{57, 63, 65, 66}\) Long term results are incompletely defined. Harrington et al. report on good to excellent long term results in 16 of 20 patients with metal prosthetic radial head spacer and a mean follow-up of 12.1 (range: 6 to 29) years.\(^{57}\) Popovic et al.\(^{63}\) report on radiographic evidence of loosening at the bone-cement interface and osteolysis of the proximal radius in patients with a bipolar floating Judet prosthesis with satisfactory clinical results after a mean follow-up of 8.4 years, possibly due to wear of the polyethylene part of the prosthesis. However, Burkhart et al. did not find this proximal osteolysis in 16 elbows with a follow-up of 8.8 years and claim that it is caused by insufficient cementing techniques.\(^{67}\)

One randomized clinical trial to compare ORIF to prosthetic replacement in Mason type III fractures is currently available. Ruan et al.\(^{68}\) found favorably results for bipolar prosthetic replacement, compared to ORIF, in trial of 22 Mason type III fractures and a follow-up of 10 to 27 months. Good to excellent result were achieved in 13 of 14 patients in the prosthetic replacement group, compared to 1 of 8 patients in the ORIF group. However, the small patient number, short follow-up and inclusion of 2 delayed cases make the reliable interpretation of these results difficult.

Once the standard treatment for type III fractures\(^3\), excision of the radial head is now reserved for isolated comminuted fractures in which a reliable osteosynthesis cannot be achieved. However, with type III radial head fractures associated injuries occur in >75% of the patients.\(^{18, 20}\) After radial head excision, elbow stability should be tested during surgery to exclude ligamentous injury. Satisfactory long-term functional outcomes have been reported after primary or delayed radial head excision.\(^{52, 69-72}\) However, wrist pain due to
proximal migration of the radius and decreased grip strength are known complications and most of these studies do not take associated injuries into account. Some authors suggest that in absence of the radial head ulnohumeral osteoarthritis is accelerated due to the altered elbow kinematics: about 57% of the load applied to the hand crosses the radiocapitellar joint in an intact elbow, but is dependent on the position of the elbow and muscle loading. Excision of the radial head can lead to valgus instability, especially in case of associated MCL injury. Ikeda et al. concluded after a study of 28 patients with a Mason type III fracture that patients treated with ORIF had greater strength and better function, compared to patients treated with resection. Excision cannot be recommended for patients who engage in prolonged heavy use of their upper extremities, such as heavy manual labourers or athletes, nor in patients with concomitant injury.

**DISCUSSION**

Radial head fractures are common and up to one-third have concomitant injuries. Although knowledge on the subject of radial head fractures and their associated injuries has increased over the past years, the optimal treatment for Mason type II and III fractures is still uncertain. The vast majority of the evidence is based on retrospective case series and only a handful of prospective studies are available. There is a strong need for standardizing fracture classification and clinician based and patient reported outcome measures, in order to make results of treatment comparable. The Broberg and Morrey adaptation of the Mason classification is preferred by the authors, as it is widely used, provides a clear definition of displacement and articular surface, and the intra- and inter-observer agreement is better, compared to other classifications.

With current knowledge, we can state that the best available guideline for treatment of radial head fractures is that Mason type I fractures are stable and can be treated conservatively, Mason type II fractures with > 2mm dislocation and > 30% of the articular surface are usually unstable and can best be treated with ORIF with good results. Mason type III fractures with ≤ 3 fragments can be treated with ORIF. In case of > 3 fragments prosthetic replacement is required. The role of radial head excision without prosthetic replacement is limited and contra-indicated in patients with associated injury. Concerning isolated Mason type II fractures with > 2 mm of dislocation, there might be a greater role for conservative treatment. Also there are reports available of satisfactory results after ORIF of Mason type III fractures with > 3 fragments.

Treatment of radial head fractures therefore remains subject of discussion. There is a need for randomized clinical trials with sufficient patient numbers. The treating physician should be aware of associated injuries and take them into account when treating patients
with displaced and/or comminuted radial head fractures in order to achieve a functional and stable elbow joint.

CONCLUSIONS

Radial head fractures are common injuries and are accompanied by clinically relevant associated injuries in over one third of the patients. Mason type I fractures can be treated conservatively. The optimal (surgical) treatment for Mason type II and III fractures is still uncertain. There is a strong need for randomized clinical trials, standardizing of fracture classification and clinician based and patient reported outcome measures, in order to make results of treatment reported in literature comparable.
REFERENCE LIST


